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Lactation Characteristics of Nine Breeds of Cattle Fed Various Quantities of Dietary Energy

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ABSTRACT: Milk yield data were collected by weigh-suckle-weigh procedures at approximately 14, 28, 56, 84, 112, 138, 156, 184, and 212 d postpartum for mature Angus, Braunvieh, Charolais, Gelbvieh, Hereford, Limousin, Red Poll, Pinzgauer, and Simmental cows over a 4-yr period. Individual cows were fed at one of four energy intake levels. Parameters characterizing lactation curves for 431 lactations from 179 cows were estimated by nonlinear regression. Differences due to breed, level of energy intake, and the two-factor interaction between breed and level of ME allowance for scale and shape parameters of lactation curves and derived estimates for time of peak lactation, yield at time of peak lactation, and for total yield for a 210-d lactation period were evaluated. Breed and energy intake level were significant sources of variation for all traits. Pooled over energy levels, daily yields at time of peak lactation of Braunvieh, Gelbvieh, and Pinzgauer were greater ($P < .05$) than those of Angus, Charolais, Hereford, and Limousin. Simmental and Red Poll were intermediate. Total lactation yield of the Braunvieh exceeded ($P < .05$) that of all other breeds with the exception of Gelbvieh. Hereford produced less milk than ($P < .05$) the other breeds. The response in yields at time of peak lactation as energy allowances increased for Braunvieh, Charolais, Gelbvieh, Limousin, and Pinzgauer cows was linear and resulted in higher yields at this time. Linear increases in total 210-d yield and times of peak lactation were observed for all breeds with the exception of Hereford.

Key Words: Beef Cows, Breed Differences, Energy Intake, Milk Production

Introduction

Production efficiency for a cow-calf enterprise may be defined in terms of the success of conversion of food energy resources to calf weight at weaning. Variation in biological efficiency exists among breed crosses or breeds (Davis et al., 1983; Green et al., 1991; Jenkins and Ferrell, 1991; Jenkins et al., 1991).

Differences in genetic potential for production have been suggested to affect efficiency (Taylor et al., 1986). Measures of lactation have been characterized by Jenkins and Ferrell (1984) and Jenkins et al. (1986) for nine breed crosses of cattle. Variation among the breed crosses for yield at time of peak lactation (kilograms per day) and total yield for a defined lactation period (kilograms) was observed. Other researchers have demonstrated that among cows of the same genetic potential for mature weight, those with the greatest potential for milk yields had lower production efficiencies (Montaño-Bermudez and Nielsen, 1990b). Montaño-Bermudez and Nielsen (1990a) reported a negative relationship between genetic potential for milk yield and pregnancy rate and calf crop percentage. Cows with higher capacity for milk yield would be expected to have greater ME requirements. If feed resources are limited, body reserves would be utilized to meet nutrient requirements. Richards et al. (1986) reported that cows with body condition scores, a measure of fat reserves, of ≤ 4 on a 9-point scoring scale had longer postpartum intervals. Current NRC (1984) feeding standards for beef cattle imply that, for cows producing milk, all cows would be

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expected to respond similarly to increased energy allowance. Following the NRC recommendations for energy allowance for all breeds may or may not result in availability of excess energy for conversion to maternal weight gains when the standards are applied uniformly across all breeds and breed crosses.

Increased understanding of breed differences for lactation traits and how breeds differ in response to increased energy availability is needed. This information will provide a basis for developing energy supplementation programs to improve reproductive performance associated with decreased energy availability. The objective of this study was to characterize the response in lactation traits of breeds of cattle representing diverse biological types fed at increasing energy allowances.

Materials and Methods

Protocol. As part of a comprehensive project to evaluate life-cycle production efficiency, lactation records of mature cows representing nine cattle breeds were collected from 1987 through 1990. Breeds represented in the study were Angus, Braunvieh, Charolais, Gelbvieh, Hereford, Limousin, Red Poll, Pinzgauer, and Simmental. Sixteen cows of each breed were assigned to the study. All cows were second parity or greater before entry into the study. At the initiation of the study, cow ages ranged from 5 to 8 yr within all breeds, with the exception of the Pinzgauer; cows of this breed were 4 to 5 yr of age. Cows were housed in open-front barns with concrete flooring. Pen size was approximately 11.7 × 6.1 m. Each pen was equipped with four electronic headgates (American Calan, Northwood, NH). Four cows and calves were housed within a pen. Breed was confounded with pen.

Each year pregnant cows were transferred to grass pastures for calving. Time on pasture ranged from 14 to 90 d. Ten to sixteen days postcalving, cow-calf pairs were returned to the intensive facilities. Cows were exposed to bulls of the same breed for a 90-d period beginning the 3rd wk in June. Calves were weaned at approximately 200 d.

Cows were removed from the study for failure to conceive during adjacent production years, for debilitating physical injury, or if chronic or acute disease was deemed to affect performance. Four replacement cows per breed were stored in similar facilities during the study. Replacement cows were introduced into the study in February each year as required. Through 4 yr of the study 35 cows were replaced.

Table 1. Composition of diets[a][b]

Ground alfalfa, %	77.5
Corn, %	17.5
Corn silage, %	5.0
ME, Mcal/kg	2.25
CP, %	16

[a]Dry matter basis.
[b]Trace mineralized blocks available free choice.

Cows received a ground alfalfa hay-based diet. Composition of the diet is detailed in Table 1. Based on previous research evaluating energy requirements of different breeds (Ferrell and Jenkins, 1985), four cows within each breed were assigned to one of four energy intake levels during the lactation period: 170, 210, 250, and 290 kcal of $ME \cdot BW^{-.75} \cdot d^{-1}$. Two replacement cows within each breed were fed 210 and two cows were fed 250 kcal of $ME \cdot BW^{-.75} \cdot d^{-1}$. Energy intake level was confounded with pen. Each cow's ration was determined by using the weight of the cow at the 6 to 7 mo of gestation of the year the cow entered the study. The ration was fed daily, with feed consumption summed and recorded weekly for each cow. Samples of feed were taken daily and composited and sampled weekly for determination of DM and CP.

Milk yields were determined approximately five to seven times from 14 to 212 d postpartum by weigh-suckle-weigh techniques. Separation of cows and calves preceded the sampling time by 17 h. The difference between calf weights before and after suckling adjusted to a 24-h basis provided an estimate of daily milk production of the cow. The suckling event continued for approximately 45 to 60 min after introduction of the calves to their dams. Cow lactation records with fewer than five daily samplings within a production cycle were excluded from the data set (n = 24). A total of 431 observations from 179 cows was included in the data set.

To quantify lactation curve characteristics, individual animal observations were fitted to a nonlinear equation: $Y_{(n)} = n \times (ae^{kn})^{-1}$ (Jenkins and Ferrell, 1984), where $Y_{(n)}$ = 24-h yield during the n week postpartum, a = scale parameter of the curve, k = shape parameter of the curve, and n = time since calving (weeks). The nonlinear solution procedure supported by SAS (1985) was used to provide estimates of the parameters. The estimates of parameters a and k can be used to calculate three values that can be described as characteristics of a lactation curve: time of peak lactation = (1/k), yield at time of peak lactation = (1/ake), and 210-d yield = $-7 \times (a \times k)^{-1} \times ((30 \times e^{-30k}) + ((k^{-1} \times e^{-30k}) - k^{-1}$.

Table 2. Analyses of variance for lactation traits of mature cows representing
nine breeds of cattle fed at four metabolizable energy intake levels[abc]

Sources of variation	df	Traits				
					Yield	
		a (× 1,000)[a]	k (× 1,000)	Time of peak lactation, wk	At peak lactation, kg/d	210-d Total, kg
Year	3	13.5	6.9**	86.1**	121.6**	4,858,347**
Breed (B)	8	413.5**	21.5**	196.1**	389.8**	10,680,782**
Energy intake level (E)	3	119.2**	48.4**	379.1**	158.4**	10,116,308**
B × E	24	224.3	8.6	90.6	109.3	3,179,378
Cows/B × E	143	1,418.2	85.4**	697.9*	546.0**	17,244,473**
Residual	249	2,329.3	82.5	875.4	441.4	9,703,874
R², %	—	50.6	70.5	66.7	78.1	85.4

[a]Sums of squares.
[b]Breed, energy, and B × E tested against Cows/B × E. Year and cows/B × E tested against residual.
[c]$y_{(n)} = n \times (ae^{kn})^{-1}$, where $y_{(n)}$ is lactation yield during the n week postpartum, a and k are scale and shape parameters, and n is weeks postpartum.
*$P < .05$.
**$P < .01$.

Estimates of the curve parameters a and k and the derived curve characteristics of time of peak lactation (PK), yield at time of peak lactation (PKYD), and total yield for a 30-wk lactation period (TOTAL) were analyzed with a model that included the fixed effects of year of lactation, breed, level of energy intake, the interaction between breed and energy intake, the random effect of cows within the breed × energy intake level, and residual using the least squares methodology of the GLM procedure provided by SAS (1985). Earlier analyses of the data included the continuous variables: calf weights (birth or weaning) or age of cow. These factors were not significant sources of variation. Therefore, these effects were deleted from the final analyses. Mean squares for breed, energy intake level, and the two-factor interaction were tested against mean squares from the cows within breed × energy level. Energy intake level was considered a discrete effect because levels represent energy allowances that can be established and repeated. Standard errors associated with the least squares means were calculated using the mean squares from the cow within breed × energy intake level.

The null hypothesis most frequently tested for an interaction is that treatment differences are similar across treatment levels. An objective to this study was to determine whether the response within a breed to increased ME availability during the lactation period for milk production characteristics differed significantly from zero. Orthogonal polynomials can be used to partition the sums of squares associated with the two-factor interaction into sums of squares associated with single df to test this hypothesis. A n degree polynomial can be fitted, where n is required to be less than the df associated with the interaction. Linear or quad-

ratic responses were evaluated. The resulting mean squares were tested against the mean squares for cows within breed × energy level. Coded regression coefficients from these polynomials were converted to observed units (Snedecor and Cochran, 1971; Anderson and McLean, 1974).

Results and Discussion

Analysis of Variance. Sums of squares associated with the sources of variation are reported in Table 2. The effect of cows within breed × energy intake level was significant or highly significant for all traits except for the estimate of parameter a; thus, this term was used to test the effects of breed, energy intake level, and the two-factor interaction. The mean square associated with a was tested against the residual. Breed and energy intake levels were important ($P < .01$) sources of variation for all response variables. Year was a highly significant source of variation for all traits except a. The two-factor interaction was not a significant source of variation for any of the traits. Despite the acceptance of the hypothesis, it is appropriate for *a priori* comparisons to be evaluated by partitioning the sums of squares associated with the two-factor interaction into single df sources of variation.

Breed Effects. Least squares mean and standard errors by breed for all traits are reported in Table 3. Estimated PK (weeks) for the Hereford breed occurred earlier ($P < .05$) than for Angus, Braunvieh, and Red Poll but at approximately the same time postparturition as for the remaining breeds. The Red Poll was similar to the Angus, Braunvieh,

Table 3. Least squares means and standard errors for lactation
curve parameters and traits for nine breeds of cattle[a,b]

				Yield	
Breed	a	k	Time of peak lactation, wk	At peak lactation, kg/d	210-d Total, kg
Angus	.41 ± .02[cd]	.10 ± .004[cd]	10.4 ± .4[cd]	9.4 ± .3[f]	1,423 ± 56[ef]
Braunvieh	.33 ± .02[c]	.10 ± .004[cd]	10.3 ± .4[cd]	11.9 ± .3[c]	1,803 ± 60[c]
Charolais	.38 ± .02[cd]	.11 ± .004[c]	9.5 ± .4[de]	9.8 ± .3[ef]	1,433 ± 63[e]
Gelbvieh	.33 ± .02[c]	.11 ± .004[cd]	10.0 ± .4[cde]	11.5 ± .3[cd]	1,697 ± 57[cd]
Hereford	.39 ± .02[cd]	.12 ± .004[c]	8.8 ± .4[e]	8.5 ± .3[f]	1,191 ± 57[g]
Limousin	.35 ± .02[c]	.12 ± .004[c]	8.8 ± .3[de]	9.5 ± .3[ef]	1,349 ± 54[fg]
Red Poll	.41 ± .01[d]	.09 ± .003[d]	11.1 ± .3[c]	10.1 ± .3[de]	1,566 ± 47[de]
Pinzgauer	.33 ± .02[c]	.11 ± .004[c]	9.6 ± .4[de]	11.1 ± .3[cd]	1,640 ± 56[de]
Simmental	.33 ± .02[c]	.11 ± .004[cd]	9.6 ± .4[de]	10.9 ± .3[cde]	1,604 ± 61[ef]

[a]c,d,e,f,g: Means with superscripts differing within columns differ $(P > .05)$.

[b]$y_{(n)} = n \times (ae^{kn})^{-1}$, where y(n) is lactation yield during the n week postpartum, a and k are scale and shape parameters, and n is weeks postpartum.

and Gelbvieh but differed $(P < .05)$ from the remainder of breeds. The remaining breeds were intermediate and did not differ from one another for PK. The estimates for PK were slightly later than the estimates reported for crossbred cows sired by Angus, Hereford, Charolais, Jersey, or Simmental bulls receiving ad libitum three diets varying in quality of diet (Jenkins and Ferrell, 1984). Jenkins et al. (1986) reported that crossbred cows fed to maintain maternal body mass during lactation and produced from seven different sire breeds did not differ in time postpartum until peak yield was attained. Among three breed crosses formed to differ in milk yield, Clutter and Nielsen (1987) observed that day of peak yield occurred later for the breed cross with greater potential for yield of milk in a 205-d lactation period.

Yield at time of peak lactation (kilograms per day) was similar $(P = .4)$ for Braunvieh (11.9 ± .3), Gelbvieh (11.5 ± .3), Pinzgauer (11.1 ± .3), and Simmental (10.9 ± .3). These four breeds produced more milk $(P < .05)$ at PK than the British breeds (Angus 9.4 ± .3; Hereford 8.5 ± .3, respectively) or Limousin (9.5 ± .3) and Charolais (9.8 ± .3). Chenette and Frahm (1981) reported that Brown Swiss- and Simmental-sired crossbred cows' daily milk yields were greater $(P < .05)$ than those of Angus and Hereford reciprocal crosses. Notter et al. (1978) reported significant sire breed differences in 12-h yield of 2- to 3-yr-old cows. They observed similar 12-h production for Limousin × Angus-Hereford (A/H), Charolais × A/H, Hereford, Angus, and A/H reciprocal cross cows, which was lower than the 12-h milk yield of the Simmental × A/H sired cows $(P < .05)$.

Total yield of the breeds ranged from approximately 1,800 to 1,200 kg pooled over energy intake level. Braunvieh yield for a 210-d lactation period

exceeded $(P < .05)$ that of all breeds except Gelbvieh $(P = .4)$. The Hereford production of 1,191 ± 57 kg was similar only to the production of the Limousin (1,349 ± 54). For cows receiving ad libitum diets of varying quality, Jenkins and Ferrell (1984) reported a range in milk yield for a 25-wk lactation of 1,564 to 1,218 kg for mature, crossbred cows sired by Angus, Hereford, Charolais, Jersey, and Simmental bulls. Jenkins et al. (1986) reported lower $(P < .05)$ predicted milk yield for a 30-wk lactation by Angus × Hereford cows fed to maintain weight during lactation compared with Braunvieh-sired cows.

Energy Intake Level. Metabolizable energy intake level affected $(P < .01)$ all the response variables. As level of intake increased, the magnitude of the scale parameter (a) increased (Table 4). Conversely, larger mean values for the shape parameter (k) were associated with the lower energy intake levels $(P < .05)$. Peak lactation was later for cows fed 210 kcal of $ME \cdot BW^{-.75} \cdot d^{-1}$ than for cows receiving 170 kcal of ME (9.2 ± .3 and 8.3 ± .3, respectively). Cows fed the higher energy intakes differed from these levels $(P < .05)$ but not from each other $(P = .4)$. Positive response to PKYD was observed with increasing levels of energy intake. A similar positive response occurred for TOTAL. Total yields for a 30-wk lactation period for the 290 and 250 kcal of ME energy intake levels were greater than for 210, which was greater than for 170 kcal of ME. The difference between 290 and 250 kcal of $ME/BW^{.75}$ was not significant.

Pooled across breeds, curvilinear responses in PK, PKYD, and TOTAL were observed as ME allowance increased. The change in PK (weeks) was described by 2.25 + .0067 × (kcal of ME × BW^{-1}) − .0001 × (kcal of ME × $BW^{-1})^2$. The PKYD (kilograms per day) increased at a decreasing rate

Table 4. Least squares means and standard errors for lactation curve parameters and traits for four energy intake levels of metabolizable energy[a,b]

Energy intake levels, kcal/BW$^{.75}$	a	k	Time of peak lactation, wk	Yield	
				At peak lactation, kg/d	210-d Total, kg
170	.35 ± .01^{cd}	.12 ± .003^{e}	8.3 ± .3^{f}	9.2 ± .2^{e}	1,239 ± 42^{e}
210	.34 ± .01^{d}	.11 ± .003^{d}	9.2 ± .2^{e}	10.3 ± .2^{d}	1,487 ± 36^{f}
250	.38 ± .01^{c}	.10 ± .003^{c}	10.7 ± .2^{c}	10.8 ± .2^{cd}	1,664 ± 37^{c}
290	.38 ± .01^{c}	.10 ± .003^{c}	10.9 ± .2^{d}	11.0 ± .2^{c}	1,701 ± 37^{c}

[a,c,d,e,f]: Means with superscripts differing within columns differ $(P > .05)$.

[b]$y_{(n)} = n \times (ae^{kn})^{-1}$, where $y_{(n)}$ is lactation yield during the n week postpartum, a and k are scale and shape parameters, and n is weeks postpartum.

with increased energy levels (PKYD (kg/d) = 1.70 + .0744 × (kcal of ME × BW^{-1}) − .0002 × (kcal ME × BW^{-1})^2. As energy availability increased, the rate of increase in TOTAL increased at decreasing rate (TOTAL [kg] = −415 + 16.5 × (kcal ME × BW^{-1}) − .0324 × (kcal of ME × BW^{-1})^2. Information describing the effect of increasing energy allowances on

lactation curve traits in beef cattle is limited. In comparison with information provided in a review article by Broster and Broster (1984), it is evident that beef cattle respond to increasing levels of energy intake similarly to dairy cattle. With increased energy allowance, PK was delayed and the yield at that time increased.

Table 5. Sums of squares from orthogonal separation of sums of squares associated with the interaction of breed and energy effect on lactation

Breed	df	Time of peak lactation, wk	Yield	
			At peak lactation, kg/d	210-d Total, kg
Angus				
Linear	1	38.9**	6.8	528,051*
Quadratic	1	.0	6.9	179,072
Braunvieh				
Linear	1	81.3**	42.5**	2,664,868**
Quadratic	1	.6	5.7	195,785
Charolais				
Linear	1	41.2**	19.9*	1,298,534**
Quadratic	1	.3	6.6	223,230*
Gelbvieh				
Linear	1	51.1**	60.2**	2,492,777**
Quadratic	1	1.4	.6	18,412
Hereford				
Linear	1	1.5	.0	12,680
Quadratic	1	2.2	.3	27,860
Limousin				
Linear	1	54.7**	15.9*	1,213,743**
Quadratic	1	3.4	9.3	343,545
Red Poll				
Linear	1	118.0**	8.5	1,048,309**
Quadratic	1	.4	1.8	46,333
Pinzgauer				
Linear	1	15.2	25.9*	1,326,389**
Quadratic	1	20.0*	5.2	701
Simmental				
Linear	1	29.7*	9.2	718,170*
Quadratic	1	1.9	11.6	423,265

*$P < .05$.
**$P < .01$.

Table 6. Coefficients and standard errors derived from orthogonal partitioning
of breed × energy sums of squares for lactation traits

				Traits					
						Yield			
	Time of peak yield, wk			At time peak yield, kg/d			210-d Total, kg		
Breed	Intercept	Linear	Quadratic	Intercept	Linear	Quadratic	Intercept	Linear	Quadratic
Angus	10.4	.44**	.02	9.4	.19	−.42	1,423	52*	−68
SE	± .36	± .134	± .303	± .32	± .095	± .215	± 56	± 14	± 32
Braunvieh	10.3	.76**	−.14	11.9	.54**	−.42	1,803	137**	−77
SE	± .38	± .157	± .326	± .34	± .111	± .231	± 60	± 16	± 34
Charolais	9.5	.52**	−.09	9.8	.36*	−.459	1,433	91**	−84
SE	± .40	± .150	± .335	± .35	± .106	± .238	± 63	± 63	± 35
Gelbvieh	10.0	.55**	−.20	11.5	.60**	.126	1,697	122**	22
SE	± .36	± .145	± .307	± .32	± .102	± .217	± 57	± 15	± 32
Hereford	8.8	.09	−.24	8.5	−.01	−.08	1,191	8	−27
SE	± .36	± .146	± .307	± .32	± .101	± .218	± 57	± 15	± 32
Limousin	8.8	.51**	−.29	9.5	.28*	−.48	1,350	76**	−91
SE	± .35	± .130	± .29	± .31	± .092	± .208	± 54	± 14	± 31
Red Poll	11.1	.64**	.09	10.1	.17	−.18	1,566	60**	−29
SE	± .30	± .111	± .26	± .27	± .078	± .181	± 47	± 11	± 27
Pinzgauer	9.6	.31	−.72*	11.3	.40*	.37	1,640	90**	−4
SE	± .36	± .147	± .303	± .32	± .104	± .215	± 56	± 15	± 31
Simmental	9.6	.42*	−.24	10.9	.24	−.59	1,604	66**	−113
SE	± .36	± .146	± .327	± .34	± .103	± .238	± 61	± 15	± 34

*$P < .05$.
**$P < .01$.

Breed × Energy Intake Level. Results from the orthogonal separation of sums of squares associated with PK, PKYD, and TOTAL for breed × energy intake levels are reported in Table 5. Two of the 24 df associated with the interaction term were used to fit linear and quadratic polynomials across intake levels within each breed to test the null hypotheses that responses of a given breed to increases in energy allowance are equal to zero. As level of energy intake increased, significant deviations from zero for the linear regression in PK, PKYD, and TOTAL were generally observed within all breeds. The exceptions to this statement were the Hereford for all traits, Pinzgauer for PK, and Angus, Red Poll, and Simmental for PKYD ($P = .4$). Additionally, significant deviation from zero for the quadratic terms for PK and TOTAL were observed for Pinzgauer and Charolais, respectively. Estimates of the parameters in coded units are reported in Table 6.

In dairy cattle (Broster and Broster, 1984) the response and magnitude of response in lactational traits to increased energy allowance is dependent on genetic potential for milk production, stage of production, and previous nutrition. Results from this investigation demonstrate that between-breed differences in responses exist and that these differences are not totally attributable to potential for milk production. For example, increases in energy allowance did not significantly affect peak production of Angus, Hereford, Red Poll, and Simmental. For Angus and Hereford, these results are not unexpected. However, previous reports (Jenkins and Ferrell, 1984; Jenkins et al., 1986) indicated that genetic potential for milk production characteristics of cows sired by Simmental and Red Poll was greater than that of those sired by Angus and Hereford ($P < .05$). Extrapolating from results with dairy cows, it was interpreted that their genetic potential for production exceeded that of the Angus and Hereford, thus leading to an expectation that a response to increased energy allowance in PKYD for Red Poll and Simmental would be observed. The linear and quadratic parameter estimates for PKYD for these breeds did not differ from zero, indicating that even though the marginal mean of these breeds (Table 7) differed for PKYD, the breeds responded similarly to increased energy allowance. Charolais-sired, crossbred cows were shown to be similar ($P = .4$) to Angus-, Hereford-, and Simmental-sired cows for PKYD (Jenkins and Ferrell, 1984). In our current study, a positive relationship between energy allowance and PKYD within the Charolais was observed (Table 7). As with Braunvieh, Gelbvieh, Limousin, and Pinzgauer, increasing energy allowance for the Charolais resulted in a greater PKYD ($P < .05$; Table 7). These results are interpreted as indicative of a differential response to increased energy allowance associated with breed differences over and above breed differences in milk-producing ability.

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Table 7. Relationships between lactation traits and energy intake levels within breed

| | Change in time of peak lactation, wk/kcal ME/BW$^{.75}$ | | | At peak lactation, kg/d/kcal ME/BW$^{.75}$ | | 210-d Total, kg/kcal ME/BW$^{.75}$ | | |
| | | | | Changes in measures of yield | | | | |
Breed	b_0	b_1	b_2	b_0	b_1	b_0	b_1	b_2
Angus	6.16	.0223	NS[a]	9.4	NS	929	3	NS
Braunvieh	3.11	.0378	NS	6.7	.027	501	7	NS
Charolais	3.78	.0345	NS	6.4	.019	568	4	NS
Gelbvieh	4.77	.0277	NS	5.8	.030	477	6	NS
Hereford	8.77	NS	NS	8.5	NS	1,191	NS	NS
Limousin	3.97	.0257	NS	6.9	.014	−1,387	26	−.06
Red Poll	5.01	.032	NS	10.1	NS	966	3	NS
Pinzgauer	−9.16	.187	−.0005	7.5	.020	740	5	NS
Simmental	5.59	.0212	NS	10.9	NS	−1,495	30	−.07

[a]NS = not statistically significant.

The incremental increase in milk production associated with increased energy intake is indicative of efficiency of milk production. For breeds responding to increased energy allowances, the efficiency of conversion of ME to milk was less than that reported for dairy cows (NRC, 1988). A substantial portion of the differences in efficiency may be attributable to the effect of collection protocol. The dairy estimate is derived from direct daily milking, whereas weigh-suckle-weigh procedures were used in the present study. The most likely bias of the weigh-suckle-weigh procedure would be an underestimation of the response in milk yield to increasing energy allowances. This underestimation could result in lower estimates of lactation efficiency, as observed in the present study.

With the exception of the Hereford, increased energy allowance delayed the PK for all breeds (Table 7). Total yield for a 30-wk lactation period responded positively to increasing energy intake levels for all breeds except Hereford. Increased TOTAL yield may result from delayed PK, greater PKYD, and greater persistency (Notter et al., 1978). Persistency (a measure of the average rate of decline in yield from PK) cannot be directly determined from the equation describing lactation curves used in the present study. For Angus, Red Poll, and Simmental, increased TOTAL could be attributable to a delay in PK and an effect on persistency. All three factors may have contributed to the responses in TOTAL associated with increasing energy allowances observed for the Braunvieh, Charolais, Gelbvieh, Limousin, and Pinzgauer.

General. Energy effects on reproductive performance in beef cattle have been recently reviewed by Ferrell (1991), Short et al. (1990), and Randel (1990). These reviewers indicate that the response in reproductive performance attributable to energy availability is expressed in a curvilinear fashion. At reduced levels of energy availability, negative effects on components of reproduction (e.g., return to estrus, conception, etc.) can be manifested. By increasing energy availability, the degree to which these effects are expressed can be reduced, but the rate of change decreases at higher intake levels. Continued increases in energy availability do not necessarily result in favorable improvements in reproductive performance (Richards et al., 1986) and, at excessive levels, may become deleterious. Presently, the level of energy availability at which energy does not limit reproduction is not known precisely. Because the optimum is not defined, surrogate indicators have been and continue to be identified (e.g., body condition scores, target weights, and weight to height ratios). Use of indicators such as these reflects the acceptance of the concept that energy "availability" includes energy resources both endogenous and exogenous to the animal. Traits such as those listed above represent attempts to measure the endogenous energy resources for an animal. Research addressing the relationship between the indicator traits and reproductive performance has been conducted (Randel, 1990). Energy restriction during either the pre- or postpartum period can affect the length of time required until estrous activity resumes after calving (Ferrell, 1991). Previous research suggests that feeding practices can be employed to remove the constraint of energy availability on reproduction (Randel, 1990). Results from the present study show that breeds of cattle respond differently during the lactation period to increasing energy allowances; thus, breeds may show differing rates of maternal weight gains at similar ME intake levels.

Richards et al. (1986) reported that postpartum nutritional management treatment did not affect the number of days to return to estrus or the interval to pregnancy for Angus and crossbred cows. Results pooled across postpartum nutritional treatment from the study indicate that a body condition score of ≥ 5 reduces the number of days until return to estrus. Cows with body condition scores of ≤ 4 had significantly longer postpartum intervals. Houghton et al. (1990) reported decreasing postpartum intervals with increasing body condition scores for Angus $\times$ Charolais cows. These researchers also reported a significant interaction between pre- and postpartum nutritional feeding strategies.

If body condition score is positively correlated with shorter postpartum intervals, should poorly conditioned cows receive energy supplementation pre- or postpartum to improve condition scores? Based on results from Charolais $\times$ Angus cows, Houghton et al. (1990) recommended increasing feed energy allowances to poorly conditioned cows during the prepartum period to decrease the interval to return to estrus. A second recommendation stemming from this study was that if cows were thin at calving, increasing energy postcalving would be effective in improving body condition scores. This would result in a shorter postpartum interval. Energy consumed by the lactating cows is not exclusively devoted to either weight gain or lactation (Broster and Broster, 1984). This observation, coupled with results from the present study, suggests that breeds potentially can respond differentially to postpartum energy supplementation programs. The rate of improving body condition with concomitant decrease in postpartum interval by increasing the energy allowances may vary with breed or breed cross. The response by some breeds to increasing energy may be to delay the PK or to increase yield of milk at PK. Given these observations, recommendations of increasing energy allowances postcalving to improve body condition score and to reduce the postpartum interval warrant further investigation before adoption as a management practice for all breeds of cattle.

Implications

Breeds of cattle differ in measures of lactation. As the energy allowances increase, milk production may increase and time of peak lactation may be delayed. Breeds respond differently to increasing levels of energy intake. This indicates that energy supplementation programs postparturition based on current recommendations may not be the most effective utilization of food resources. The differential responses by breeds of varying genetic potential for lactation traits require that feeding standards be more dynamic. Given breed averages, feed allowances can be developed to more effectively utilize food energy in the cow/calf segment of the beef industry.

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